Understanding crowd behaviour

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Chapter 8

Discussion and Conclusion

This thesis sought to answer the question:

> Which mechanisms underlie crowd behaviour patterns?

In order to find an explanation for the generic mechanisms that underlie behaviour patterns, the first step was to study literature. Several things can be concluded from the literature. Generally, a lot of the literature on crowd phenomena is written from a practical perspective. From this literature, it becomes clear that practitioners are mainly experience-driven and only rarely act informed by the latest crowd research (Adang, 2006). However, nor does science provide the systematic knowledge that practitioners need at this stage, in spite of the existence of a body of crowd research. Modern crowd research provides empirically based descriptions of crowd behaviour, mainly focusing on specific phenomena, especially on disorder and emergency situations. Altogether, these studies do identify a number of influence factors that are supposedly relevant for crowd behaviour. However, explanations for *why* and *how* these factors exert the supposed effect are rare. The result is a large body of theories that are untestable in their present form. The studies that do provide an explanation (e.g. (Adang, 1998, 2010; Reicher & Levine, 1994; Reicher, 2001)) tend to give a specific type of explanation that only applies in a specific type of situation, , usually involves disorder or emergency situations. Disorder studies focus on explanations in the social context, whereas emergency studies focus on explanations in the physical context. Having said that, modern crowd research provides three important insights:

- Crowd behaviour is generated by individuals, i.e. agency is at the individual level and not at the group level.
- Crowd behaviour is context-dependent. Context includes both the physical and social environment.
- Crowd behaviour is dynamic: there is a continuous interaction between individuals and the environment over time.

These insights reflect the importance of the interplay between individuals and their environment in generating crowd behaviour patterns. With regard to these insights, one cannot help but notice that the explanations given do not incorporate the way

individuals process information and choose behaviour. Consequently, in crowd research, references to theories from the cognitive sciences are rare.

Given the current state of knowledge gained from literature and the fact that the field is restricted in the sense that it cannot perform controlled experiments, two requirements can be formulated. These requirements have to be met in order to increase the understanding of the mechanisms that underlie crowd behaviour patterns: 1) a theoretical model that reflects the dynamic interplay between individuals and the environment is required, and 2) a method that allows to test this theory is required. The CROSS model incorporates these two minimal requirements. The CROSS model represents a theory of crowd behaviour that was explored by means of simulation experiments.

The CROSS model is developed by using an integrative, multi-level and situated approach. The model is integrative, as relevant knowledge from the social and cognitive sciences is integrated into the framework. The model has multiple levels, including the level at which behavioural patterns emerge (i.e. the group level), the level at which behaviour is generated (i.e. the individual level), and the level at which behaviour is affected (i.e. the cognitive level). The model is situated because individuals are embodied (i.e. the physical aspects of having a body) and embedded (i.e. the mental state related to a context and experience at a certain moment). The CROSS model thus incorporates the three main insights from modern crowd research, plus it moves a step further in describing behaviour at the cognitive (i.e. intra-individual) level. The cognitive level is a reflection of the understanding of individuals as human information processing systems. Two main processes describe the interplay of an individual with its environment, involving perception and behaviour selection. The level of detail provided by the cognitive level of description allows for relating the level at which behaviour is affected and generated (the cognitive and individual levels) to the level at which patterns emerge (the group level). To answer the research question, this multi-level approach is taken.

This integrative, multi-level and situated approach offered by the CROSS model leads to detailed explanations. It also forces explicitness when incorporating theories and ideas and helps to make them more concrete and precise. The framework demands specific descriptions of crowd behaviour, including the way individual behaviour is affected and generated, what it means to have a body and to be embedded, what it means to be placed in a physical and social context, and finally how this all evolves over time. The development of a computational model contributes to the explicitness in the CROSS model to an even larger extent. It shapes the way in which every potential variable, idea or theory is framed, because these variables must be so specific that they can be represented in a form that can be understood by a computer. These fundamentals, together with the precision that a computational model enforces, entail a certain view on crowd phenomena. When a potential factor, idea or theory is considered, it is framed, which clarifies immediately whether the idea or theory is precise enough for this model. For example, leadership research mostly concentrates on describing how an effective leader can be found, how a leader can be 'made' or in what kind of setting a leader becomes effective. The leadership literature does not focus on describing how a leader actually influence other people, moving beyond terms like charisma or motivation. From the perspective presented in the CROSS model, the actual influencing is the first point of focus, a point that is crucial

in describing the behavioural dynamics. The CROSS perspective forces to concretise this specific part of influencing concerning leadership. The differences in perspective become immediately clear, which allows to distinguish between the relevant and irrelevant parts of those ideas or theories. Furthermore, the CROSS perspective supports the incorporation of the relevant factors, ideas and theories without losing the overview in the multitude of potential factors, ideas and theories. In other words, CROSS supports both a multi-disciplinary and an integrative approach. With regard to the CROSS model itself, the level of concreteness results in transparency concerning about the strong and weak points of the model. This stimulates the iterative process of improving the model where needed in order to answer the research question.

Simulation was chosen as the method to test the model. Simulation provides both experimental freedom and a rigid scientific structure, which is exactly what crowd research needs. The design approach that was chosen to represent the CROSS model in a computational form is multi-agent systems. Multi-agent systems allows to incorporate all the elements that are required: the multiple levels, the individual-level richness (i.e. the cognitive level), the role of context and dynamics. To be able to conduct experiments, the theoretical model was formalised into a computational model. For this step, each concept and/or relationship had to be defined in variables and methods that could be understood by a computer. Formalisation is an important and challenging step that involves the use of existing knowledge or data and a creative approach[1] in order to transfer the ideas into code. In the transfer analogy, intuition and the expertise of others play a role, but these all have their pitfalls. To be able to explore new areas, testing (i.e. verification and validation) is crucial (Abbott, 2003). Testing reveals the strengths and weaknesses of the model and therefore the credibility of the outcome.

Two experiments were conducted with the CROSS model to gain a better understanding of crowd behaviour patterns. One experiment explored the effect of a physical factor (i.e. density) on behaviour clustering, and the other explored the effect of a social factor (i.e. leadership) on behaviour clustering. When interpreting the results, it is important to realise that the exploration of density and leadership refers to the CROSS model and not to the real world. This makes any real world inference a hypothesis rather than a fact. Each experiment led to several factor-specific insights, but, most importantly, to insights at a more generic level. In the density experiment, it became clear that density is an important factor to take into account when investigating crowd behaviour patterns, because it has a strong impact on what an agent perceives as well as on which behavioural options an agent has. Furthermore, density also has an indirect effect that does not concern only the physical environment. Fluctuations in density level can change the social environment, which influences *what* is perceived. This is because perceiving more people implies being influenced by more people. The leadership experiment demonstrates the importance of the role of the social context in behaviour specific choices. Which behaviour is relevant or suitable appears to be a function of both the social environment and the internal state of an agent. The experiments show that the physical context describes a more generic relationship by influencing the behaviour selection process in terms of the time that is

[1] Creativity refers to the innovative part of scientific research. The scientific imagination a psychologist uses to design a good experiment for instance. See Abbott (2003) for heuristics in being 'creative'.

available to compare and choose behaviour. The social context, however, describes a more specific relationship as it is the affected behaviour-specific aspects that change the type of patterns that arise, not the pattern size itself.

Even though density and leadership were represented in a basic form, the experiments conducted with the CROSS model already illustrate the distinctive contribution of the CROSS model compared to other, traditional models, mainly by the level of detail provided and the multi-level description. In addition, the results of the experiments confirm the importance of the role of context. For instance, it is clear that density has a stronger effect than solely the bodily impact. It is important to realise that a physical influence factor, such as density, does not necessarily lead to a specific *type* of behaviour. It can, however, affect the behaviour patterns that arise indirectly. The leadership experiment, on the other hand, stresses the role of social context in the type of behaviour that emerges. Both the density and leadership experiments raise several important issues in relation to seeking an answer to the research question.

In general, the research of this thesis demonstrates the importance of the interplay between the physical and social context in behaviour. Due to the monodisciplinary orientation of most crowd research, the interplay between multiple factors is traditionally neglected. Obviously, including context should be based on relevance, rather than on field-specific preferences. Due to the multitude of potential factors, simplicity is needed in order to understand the dynamics of the model. It was not the aim of this thesis to create a "complete" model that would incorporates all potentially relevant influence factors at this stage. In fact, this would make the model less transparent, making it more difficult to find the mechanisms. The model is developed in such a way that theories and ideas can easily be integrated and that factors can easily be changed, replaced or added. For this study, a basic formalisation was provided that included one physical and one social factor. The flexible and easily adaptable character of the structure is suitable for exploring general mechanisms, allowing for all kinds of factors to be included easily. From the perspective of crowd research, this thesis represents an unusual approach, applying a design methodology within an empirical methodology. The design and formalisation of a simulation is part of an empirical cycle, like other empirical research. This thesis demonstrates that this approach can lead to meaningful results.

8.1 Answering the research question

The research question can be answered by combining insights from the literature, the theoretical/computational CROSS model and the results of the experiments. In the first place, *the mechanisms that underlie crowd behaviour are the same mechanisms that give rise to behaviour in general.* This is an important realisation as it makes clear that crowd behaviour should not be considered as a special kind of behaviour that needs its own set of dedicated theories. Therefore, the whole body of knowledge on human behaviour is potentially relevant. This answer is actually defining the search space in looking for mechanisms. Secondly, *explaining the mechanisms underlying crowd behaviour patterns always requires a complete image of the interplay between individuals and their context*. This does not imply completeness in the sense that all relevant factors must be incorporated; it means that the interplay between the factors one chooses

to describe in relation to both context and individuals must always be addressed. It is impossible to meaningfully study individuals isolated from their context; placing them outside a crowd context would make no sense. However, exclusively regarding the context without considering the individual perspective would be meaningless too:'What affects this individual?' and 'How does the individual interpret this context given his current internal state?'. To reveal the mechanisms, the interplay between individuals and their environment must always be taken into account, regardless of the factors under consideration. Thirdly, several generic mechanisms can be derived:

- The physical context predominantly determines what influences behaviour, thus affecting the size or number of crowd behaviour patterns.
- The social context predominantly determines how behaviour is influenced, thus affecting what type of behaviour is exhibited in crowd behaviour patterns.
- The internal state of the cognitive system determines which behaviour is chosen.

The physical context predominantly determines what influences an individual in terms of what he is able to perceive and what could thus potentially affect his behaviour. For instance, the function of a fence may be to block the perception of an attractive point, to minimise pushing or to guide movement in a certain direction. Of course, there is no direct effect on behaviour, but there are direct constraints on the freedom of movement. The physical context does not distinguish behaviour on the basis of contextual relevance, but on the basis of practical possibility[2]. The social environment predominantly affects an individual concerning the type of behaviour that he considers more relevant in a certain setting. The different influences concern the internal representations of a person's relationships with others (i.e. interpretation). In the end, the individual will choose behaviour on the basis of his internal state that is continuously changing due to the influence of the context.

8.2 The contribution of the CROSS model

To develop the CROSS model, theories and ideas were used and adapted from a diversity of research areas. In turn, the CROSS model can contribute to these research areas too, exactly because of its integrative approach. The CROSS model has researchers and practitioners look at crowds from a different and narrative perspective. By doing so, it sheds a different light on the traditional way of using theory and methods in relation to crowds. Below, the contribution of the CROSS model to crowd research, to the cognitive sciences, to the social sciences in general, and to computer science/simulations will be set out. In addition, the practical implications of the CROSS model will be discussed.

8.2.1 Crowd research

The main contribution of the CROSS model obviously concerns the field of crowd research. This aim of this thesis was to develop a generic, testable theory as well as a

[2]Please recall that the extreme settings are not taken into account here. In case of an emergency (e.g. facing a fire), the context does directly influence the type of behaviour (e.g. fleeing). The aim is to describe a general principle that is derived from the influence the physical context has.

methodology for understanding crowd behaviour. The answer to the research question reflects the main theoretical contribution: the only way to understand crowd behaviour is by explaining behaviour in general. The CROSS model expands the body of existing knowledge on crowd behaviour patterns by incorporating theories on individuals, especially theories in which individuals are consideered human information processing systems (i.e. cognitive systems). Both the relevance of context and the way influences act on an individual concern crucial steps towards a better understanding of this complex phenomenon. The methodological contribution lies in the use of simulation as a method. Simulation fulfilled the need of crowd research to conduct experiments and thereby test theories. Simulation provides in the methodological steps to gain a better understanding of crowd behaviour. Experimental freedom is limited only to the level of description and detail that is chosen. A high level of detail was used for the cognitive level, providing a lot of richness in the explanations. The formalisation of the theoretical CROSS model adds even more detail and concreteness, and, in this way, leads to an adapted and thus new version of the theory it represents.

8.2.2 Cognitive sciences

The CROSS model is built on the view of an individual as a cognitive system, i.e. a human information processing system. This view originates from the cognitive sciences. The functional-level description of the mental processes was adopted from cognitive architectures which originates from a perspective to develop a unified theory of cognition (Newell, 1990). In developing the CROSS model, embeddedness is reflected by the social setting of a crowd event. Cognitive representations of social concepts are hard to find in cognitive sciences. This is mostly due to the fact that social aspects are not the point of focus for cognitive scientists, who tend to study individual cognition in depth (Sun, 2008). When studying human cognition, they focus on so-called higher cognition, including planning, language, and reasoning, and refrain from making direct references to the social environment of individuals. In this thesis, the focus lies on behaviour in a dynamic social context. In other words, the social environment is crucial. Although the types of behaviour involved generally concern lower cognition, it is fairly complex to represent them due to the constantly changing nature of the world and the complexity of social interactions.

The research in this thesis concentrates on understanding behaviour in a social world. By taking the stance of an individual as a cognitive system, the exploration concerns the social world being represented at a functional level. For the cognitive sciences, this is bridging their field to the social sciences. In addition, it evokes a discussion on how to represent the social world on the cognitive level. After all as Boden puts it: "Cognitive science is not the science of cognition. Or rather, itis not the science of cognition alone." (Boden, 2008, p. 669).

8.2.3 Social sciences

For the social sciences, the same argument as for the cognitive sciences holds: the integrative, multi-disciplinary and computational approach explores the boundaries of the field and sheds new light on traditional views and approaches. The social sciences are mainly concerned with theories that relate a minimal set of relationships,

use a monodisciplinary view, and employ an intentional level of description. New insights can be gained by taking a different perspective on crowd behaviour. The CROSS model, for instance, broadens the scope to describe a wider range of behaviour and contribute to a better understanding of crowd behaviour in general. Isolating instances of behaviour or interactions from the event would provide insight into very specific situations, but not into the general dynamics in a crowd. The use of a structure in which existing theories, integrated with other theories, can be placed allows for the coverage of a broader range of behaviour. The flexible and easily adaptable character of the model allows for the comparison of multiple theories, either together, isolated, or in comparison to each other. In addition to taking a broader perspective, the use of knowledge from other domains concerning human behaviour (e.g. the cognitive sciences) is complementary for the social sciences. Up until now, these other domains are not used very often. It seems that the social and cognitive sciences do not interact with each other, even though they do share research topics. Of course, their focus is different but the topics are still the same. The integration of these theories into the CROSS model can facilitate using knowledge that is relevant and available. The level of description used in the CROSS model can also be seen as a contribution to the social sciences. The cognitive level adds detail, concreteness and precision to a theory, but even more importantly, it makes the theories comparable as they are all described in a similar way. In this way, communication about theories and ideas is made easier and the possibilities for integration become more realistic. In addition, the use of simulation in the social sciences enables to study complex research areas, such as social processes, and to explore the effects of different settings.

8.2.4 Computer science/simulations

In general, computer simulations of human behaviour in general are mainly developed in terms of computer science notions, such as reusability of software patterns, object-oriented programming, scalability, computational cost, or 2D/3D visualisation, to name only a few. For example, simulations of crowds tend to simulate behaviour, which usually involves locomotion or movement on the basis of physical characteristics and laws. This way of modelling behaviour, without taking the social context into account, will always limit the behaviour an agent will be able to display. This study shows that modelling behaviour is not easy, but most importantly, it shows that the role of context, both physical and social, should not be ignored.

This research and other social simulations describe behaviour, not the physical laws of movement. A simulation based on physical aspects alone would not be able to reproduce the group that turned against the police at the beach festival in Hoek van Holland, while others continued partying. This shows not only the importance, but especially the potential and applicability of developing a simulation that incorporates human behaviour[3].

[3] To develop simulations that are capable of representing realistic or believable behaviour does not necessarily imply using computationally heavy models. This depends on the simulation and the knowledge available of a certain situation. The aim of this thesis was to gain knowledge that required a high level of detail. Whenever the knowledge is available to the modeller, a formalisation to more simple rules allows for the development of lighter behaviour models.

8.2.5 Practice

Although the research in this thesis represents a theoretical study on crowd behaviour, including an exploration in a simulated world, the potential contributions for practice are already visible. The CROSS model raises awareness for the important ingredients determining crowd behaviour: context, individuals and the dynamics between them. Too often, the tendency is to look at undesired outcomes, without taking the relevant elements into account that contributed to these outcomes. The CROSS model helps to create the whole picture, for instance, by emphasising the different role of the physical and social environment, rather than focusing on a specific group or behaviour. It is important to be aware of the kind of physical context that individuals may find themselves in when in a crowd. Which information reaches the individual and may thus affect them? It becomes a strategic choice to make some attractions points 'invisible' in order to make sure that people do not start to hurry and push (e.g. when they see the stage of a festival while standing in a long queue). On the other hand, it could be a strategic choice to make certain attraction points 'visible' in order to put people in a more patient mode (e.g. information that the concert has not started yet). Following this reasoning will lead to (re)consider a number of choices in both the design of events and the management of crowds. In terms of the physical environment, it would be relevant to examine what is perceptually available to individuals before exploring potential influencing strategies. For one, the measures following from the strategies must reach the individuals involved, and secondly, the individuals must be able to act in the desired way (e.g. when it is too crowded, influences on movement are fruitless). In terms of the social context, it is important to know who one is dealing with, as influencing strategies must to 'fit' the setting. For example, when a crowd is directed in and out of a city in relation to an event, it makes a difference whether the guests know the city, in terms of how they let themselves be steered towards or away from points of interest. This thesis states clearly that it is not possible to draw conclusions on behaviour choices based on physical factors alone. This view directly contradicts a common view in the field of safety management. A recent example of this can be found in the emergency crowd example of the Love Parade in Duisburg, Germany (see chapter 1), where it was claimed that the catastrophe was the inevitable outcome of physical factors. The social context cannot be ignored.

8.3 Future

The results and conclusions of this thesis open the way for several exciting possibilities for future directions of both research and practice.

Research.

By developing, discussing and experimenting with the CROSS model new questions and topics that may give direction to future research for a further understanding of crowd behaviour will be generated:

Downward causation. The CROSS model represents crowd behavioural patterns as an emergent process. Group level patterns will arise bottom-up due to interactions

between individuals. It would be interesting to explore the role of downward causation (i.e. top-down influence) in order to investigate the way group level patterns affect individuals. The dynamics between the cognitive, individual and group levels, the so-called micro-macro link (Sawyer, 2003; Gilbert, 2002) will increase the level of realism in modelling crowd behaviour. Another option would be to explore the impact of observing another group, for instance the the police, and study intergroup dynamics. Modern crowd research emphasises intergroup dynamics to explain escalation processes (Adang, 2010; Reicher, 2001). These concepts of 'in-group/out-group' and 'group membership' concepts invite to elaborate on the cognitive representation of groups, but also of the representation of oneself as a group member. In addition, the effects of feeling part of a group and perceiving another group can be explored, as well as how these notions change over time. Defining and integrating these concepts would initiate an important discussion on representing and combining these concepts, not only in crowd research, but also in the social and cognitive sciences. This is an intriguing area to enter, with a lot of open questions.

Experience and communication. Other paths worth pursuing, inspired by practical relevance, include the role of experience and communication. Experience, for example, can be related to normative behaviour at crowd events, or to the distinction between experts and non-experts in non-formal settings. Experience is in this sense related to what an agent considers 'normal behaviour' at such an event, based on its previous experiences. Including communication would allow to explore the influence of the local vicinity that is not restricted to spatial vicinity. The use of mobile phones is a good example of this. In this way, information could be explored as an intervention but also as a tool to coordinate or cooperate.

Behaviour variety. An increase in the amount of behaviours a CROSS agent could perform would be a relevant extension of the model. As a first step, it would be a good idea to provide a more realistic representation of the range of behaviours shown in real-life crowds by including behaviour that does not necessarily involve horizontal movement. The second improvement of the model would be to make the behaviour expectations dynamic. These expectations are crucial in selecting behaviour. However, currently, they are fixed. It would be interesting to have the expectations change on the basis of experiences over time, which would represent learning. For instance, learning that certain behaviour is more favourable in a certain a setting would give rise to norms. This way, personal preferences may arise, or normalised behaviour may form. The learning effect on expectations will provide important dynamics concerning the internal relevance of behaviour and thus of behavioural patterns at the group level. These suggestions have consequences. Adding an internal relationship, or dynamics to the behaviour expectations requires for theories or empirically based knowledge to incorporate or study the effect in such a way that it helps to understand crowd behaviour dynamics.

Emotions. A concept that is often mentioned when talking about crowd behaviour is emotion. It was briefly mentioned that a setting of the CROSS model, i.e. the internal state of an agent, could be interpreted as a reflection of emotion. Studies

on emotion differ in the way they define emotion in terms of description level (intra-individual, inter-individual, group, culture) and perspective (evolutionary, social). The way emotion is defined has strong implications for the explanations that are provided. It would be a good idea to make an effort to clarify how emotion can be linked to the CROSS model.

Group measure for crowd behaviour patterns. In the CROSS model, behaviour clustering was used as a group measure. This measure represents behaviour patterns in a crowd, i.e. the identifiable subgroups that change over time. Currently, the measure does not represent the number of subgroups or the size of the subgroups. However, it might be interesting to distinguish between the different subgroups and to discern between subgroups on the basis of behaviour, size and changes in composition. This is, of course, inspired by the results of the leadership experiment, which showed the need for a measure that incorporates differences in behaviour. Naturally, this leads to the question of how to design a proper measure, what it does and does not represent, and to what extent it can be used for real crowds. Designing a group measure involves a theoretical, computational and practical debate.

Validation. The most important future direction concerns further validation of the CROSS model. In particular, its social and cognitive plausibility and the empirical validation of the CROSS model should be sought. Social and cognitive plausibility is emphasised as the description of the individual's internal world must be grounded. The use of a structure and the way knowledge is represented in memory is adopted from a cognitively plausible architecture. However, at present, not everything can be grounded. For instance, the way in which memory elements represent and change the social world due to the interaction with the world concerns an assumption that has not been empirically tested. Further research in both the cognitive and the social sciences is needed to develop these kinds of models. The second validation need concerns closing the empirical loop to real-world conclusions. A combination of empirical and simulation studies would foster further understanding by making empirical data available for setting and validating simulations. Combining the two would also allow to conduct specific empirical studies based on the insights gained from simulation results. For example, the measure of behaviour clustering is developed in such a way that it can function as a measure in real crowds. Gathering data of crowds with varying density levels at a festival would supply input to further validate the CROSS model. In addition, observational studies could be conducted that incorporate this 'complete-picture approach', where both physical and social factors would be registered and systematically compared.

Practice.

Crowd research has an obvious link to reality and the knowledge generated by crowd research can be and is being used in practice, e.g. to assist in training, event preparations or decision-making processes. This thesis addresses fundamental questions and theories concerning crowd behaviour, which are however, still standing far from practice. Nevertheless, the possibilities for future usability are obvious. From a practical perspective, it would be particularly relevant to explore those crowd phenomena that

are also interesting for LEOs. In addition to generating relevant knowledge, the use the simulation of crowd behaviour has other potential uses for practitioners.

Visualising theory. The CROSS model is already capable of visualising a theory and shows what happens in a crowd. In this way, practitioners may be confronted with the current state of knowledge in a more accessible form than when they are provided with books or given lectures. A simulation enables to get a feeling of what happens. A theory can be rather complex to explain, especially due to the dynamics in crowds. It may be grasped more easily when visualised.

Training. LEOs usually receive a special training to deal with crowds. Actually dealing with crowds is where the LEOs gain their real experience. The use of a simulation training tool or Virtual Reality (VR) could provide LEOs with another, flexible, option to gain more experience. A tool for training requires further development of the CROSS model, but first of all it requires more fundamental knowledge of crowd behaviour, more than is available right now. In the CROSS model more scenarios should be developed, with behaviour being more closely related to reality. To support learning, a tutor system behind the screens should be developed as well.

Decision support Another type of system that could in principle be developed from a model like the CROSS model is a decision support system for crowd management. Such a system could support strategic decision making when preparing for crowd events. An application could help ensure that all relevant questions are addressed in the preparation of an event. Another application could make clear what the consequences of these decisions are. These applications are part of the distant future, as they require fundamental knowledge of crowd behaviour, but also general knowledge about behaviour itself and especially specific context-related knowledge in terms of scenarios.